Concen-training System

Group D

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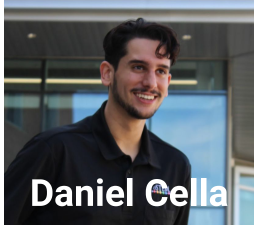
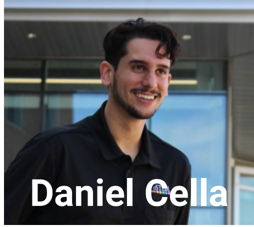
Agenda



- Project Overview
- Hardware
- Software
- Testing
- Administrative

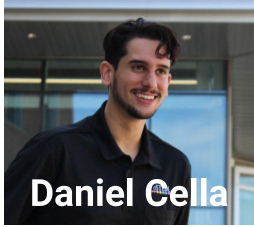
Project Overview



Problem Statement

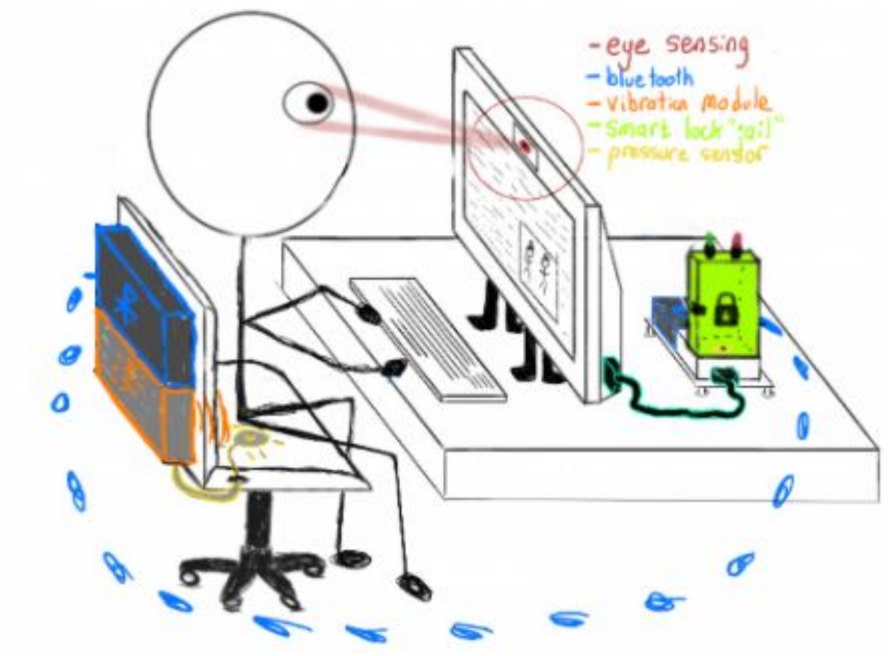
- In the current age, instant gratification and technology rule the lives of the masses. Although smartphones offer quick access to limitless informative resources, much of the time people are distracted by other things such as social media, mobile games and other trivial diversions.
- Personal Note: We have found it difficult to study effectively with our phones in our vicinity

Goals & Objectives (Project and Personal)



- **Project:**
  - Create an electromechanical reinforcement system to improve study habits.
  - Help train users to maintain focus during online classes, studies, or work.
  - Utilize positive reinforcement to promote good study behaviors.
  - Utilize negative reinforcement to deter poor habits.
- **Personal:**
  - Improve skill sets across engineering disciplines.
  - Circuitry & physical layout design experience through multiple PCB designs.
  - Electromechanical design experience through sensor development and housings.
  - Coding integration experience with multiple microcontrollers.

Design Approach/Proposed Implementation



An MCU connected to the user's computer controls the lockbox module and the chair module to track the user's focus and alert them once focus is lost.

Module Description

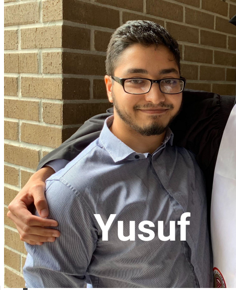
Lock Box

- Holds User's Phone to Minimize Distractions
- Store PCB used to Control Lock Box Hardware and Communicate with Chair Module
- Weight Sensor to tell when Phone is Placed Inside

Chair

- Senses When User is Seated
- After Set Time Without Focus, Alert User via Vibration
- Contains All Components Needed for Chair Operation
  - Vibration, PCB, Weight Sensor, Power

Specifications



- The eye-tracking system should be greater than 90% accurate and be able to register a user within 1 meter
- The chair should register a weight of at least 50 lbs or greater, up to 200 lbs
- The lockbox should register a weight of at least 0.3 lbs
- The total set-up time for the system should not exceed 10 minutes
- The eye-tracking system must note inattention within 30 seconds
- The vibration system must alert the user of inactivity within 30 seconds of inattention

Constraints

- Lockbox must:
  - fit majority of cellular devices
  - Utilize weight sensor able to register devices
- Chair module must:
  - Use motors strong enough to alert user
  - Use motors compact enough to fit comfortably in chair module
  - Be comfortably compact and portable
- Software language must:
  - Be compatible with computational devices
  - Be compatible with operating system

Constraints (continued)

Economic: Our project has no sponsors, fully funded ourselves

Environmental: Florida is humid, could affect electronic parts

Social/Cultural: User interface only in English for the time being

Health & Safety: Lockbox must have emergency release within 60 seconds

Manufacturability: Limitations on parts due to microelectronics shortage

Sustainability: Possible need to get new batteries after current ones go bad

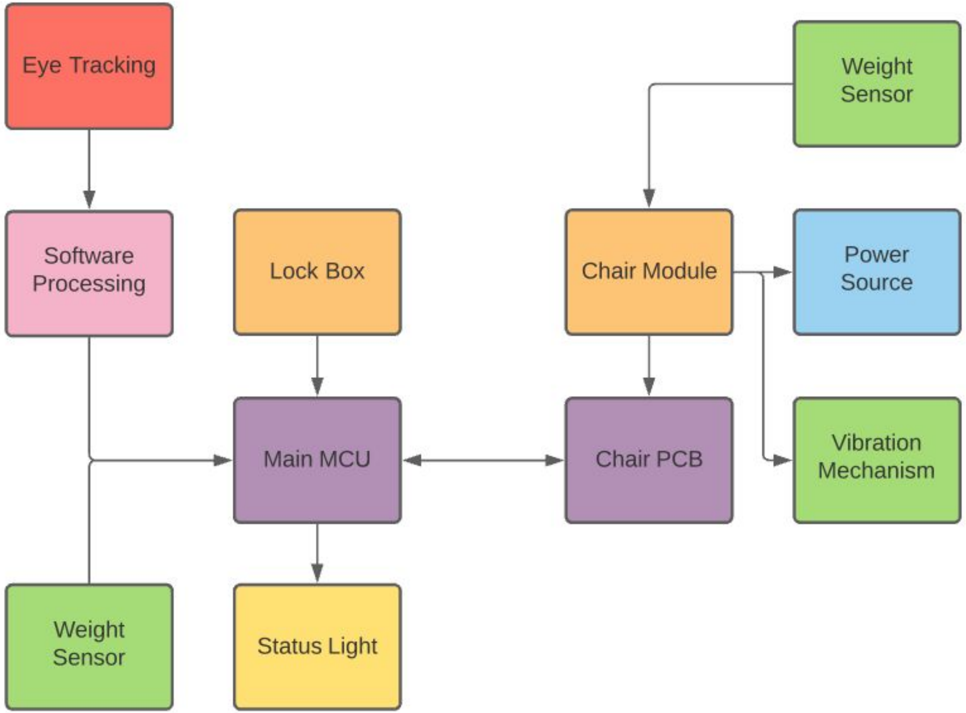
Ethical: Privacy concerns, eye shape for eye tracking

Related Standards

- IEEE 1625-2004: Standard for Rechargeable Batteries for Portable Computing
- IEEE P7004.1: Recommended Practices for Virtual Classroom Security, Privacy and Data Governance
- IEEE 802.15.1: Standard for Telecommunications and Information Exchange Between Systems - LAN/MAN - Specific Requirements - Part 15: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Wireless Personal Area Networks (WPANs)
- IEEE C95.1-2019: Standard for Safety Levels with respect to Human Exposure to Electric, Magnetic and Electromagnetic Fields, 0 Hz to 300 GHz

Hardware

Hardware Block Diagram



Blue - Danny
Green - Mitch
Red - Yusuf
Yellow - Zoe
Pink - Yusuf & Zoe
Purple - Danny & Zoe
Orange - Danny & Mitch

Hardware Overview

- Eye Tracker
- Lockbox Module
- Chair Module

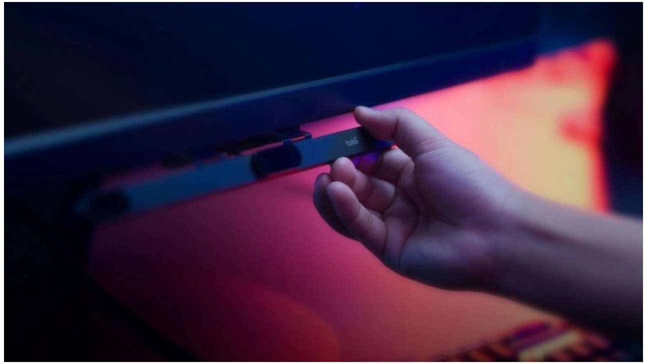
Eye Tracker

Eye Tracking Overview

- Infrared eye trackers vs Webcam eye trackers
- Pros and Cons of Webcam eye tracking
- Pros and Cons of IR eye tracking

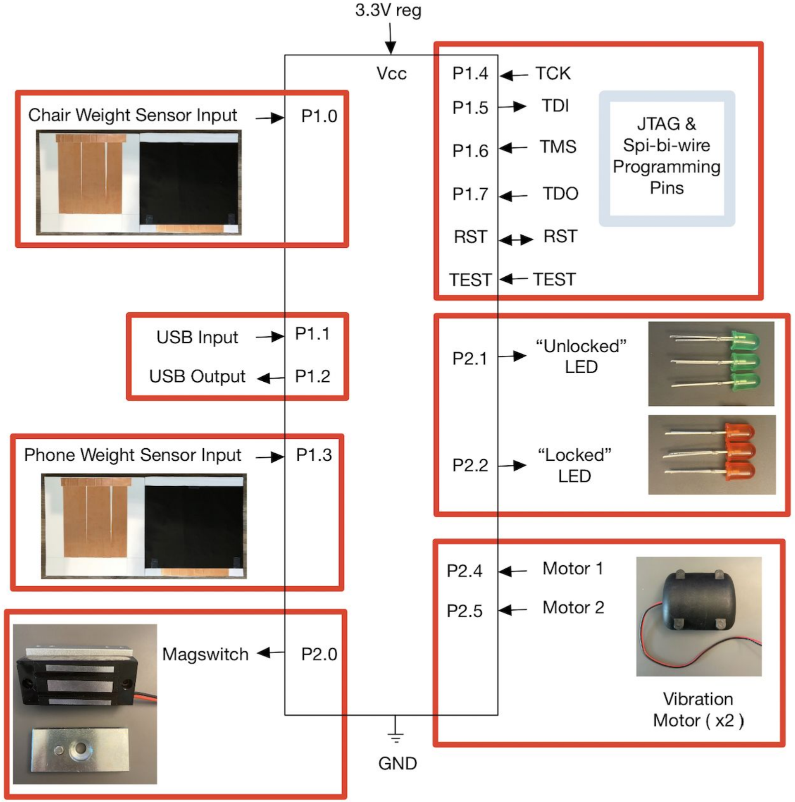
Eye Tracking Devices

- Mounted camera vs wearable device
- Tobii Eye Tracker 5
- Tobii Pro
- Why not design an eye tracker?



Main Desk Module

Main MCU Connections (MSP430G2553)



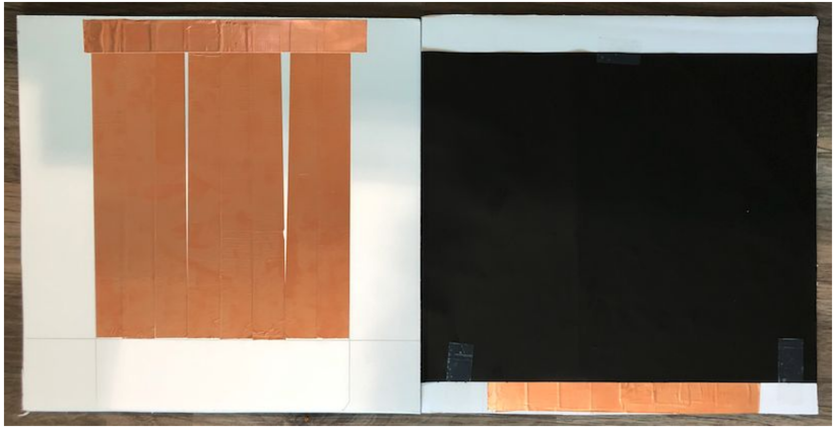
Microcontroller Selection

Features	Computational Device					
	MSP430G2553	MSP430FR6989	nRF52840	RP Zero [W]	RP 4B	RP Pico
Price	$13.29 (free)	$24.00 (free)	$12.95	$10.00	$35.00	$4.00
Memory Size	512B	128KB	256KB	512MB	2/4/8GB	264KB
GPIO	24	83	48	54	58	23
Operating Voltage	1.8 V - 3.6 V	1.8 V - 3.3 V	1.7 V - 5.5 V	3.3 V - 5 V	3 V - 5 V	1.8 V - 5.5 V
Clock Speed	16 MHz	16 MHz	64 MHz	1 GHz	1.5 GHz	133 MHz
Bit Depth	16 bit	16 bit	32 bit	32 bit	64 bit	32 bit
Supported Languages	C/C++	C/C++	C	Python/C++	Python	C/C++/ MicroPython
Communication	UART, IrDA, SPI (2), I2C	UART (2), I2C (2) SPI (4)	UARTE (2), SPI (3), I2C, BLE 5.0	mini HDMI, mini UART, SPI (2), I2C, [BLE 4.1, WLAN]	mini UART, SPI (2), I2C, BLE 5.0, 2.4/5.0 GHz WLAN,	UART (2), SPI (2), I2C (2)

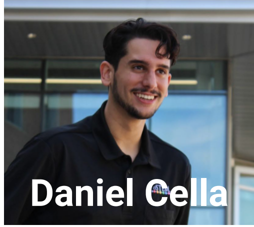
- Experience with MSP430s
- Experience with C
- UART needed for wireless communication
- Have MSP430s for testing purposes

Lockbox Weight Sensor

- Velostat
  - Piezoresistive Material - Resistance changes as pressure is applied
  - Placed between two conductive surfaces
  - Apply voltage to one side
  - Change in reading on other side
- Only Reading Phone Weight
  - Sensor does not need to read high weight
- Uses Minimal Space
  - Allows more space in box for phone



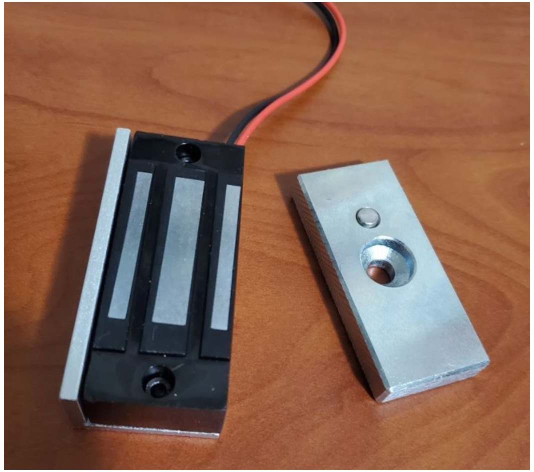
Item Name	Voltage Requirement	Size	Weight Range	Cost
Strain Gague Load Cells	2.6 - 5.2 V	3.4 cm x 3.4 cm	≤ 441 lbs.	$12.99 (pack of 4)
FlexiForce Sensors	0.5 - 5 V	1.25 in x 2.24 in	≤ 7000 lbs.	$90.43 (pack of 4)
Velostat Weight Sensor	5 V	12 in x 12 in	Test to Determine	$4.95 (per sheet)



Magnetic Locking Switch

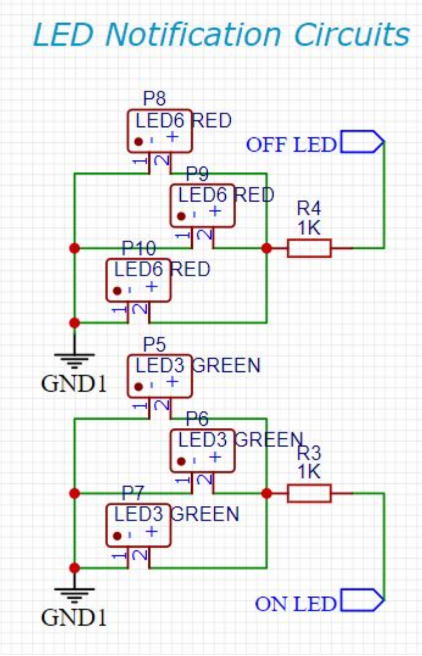
- Magnetic locking mechanism used to ensure that the user's phone is unreachable during study sessions.
- Takes 12V of power to operate
- Is something typically used for extra home security along doors.
- Chosen to limit amount of mechanical parts in the design. Can be turned off/on simply by power connection.

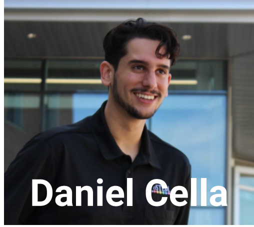
Item Name	Cost	Size (l x w x h)	Mechanical part	Pull rating	Driving Voltage
Mounted flange magnet	$40-$60	1 1/8" x 7/8" x 2 1/8"	Flange: "turn the handle to activate"	95lbs	N/A
Door Cabinet Magnetic Lock	$16.86	80 x 40 x 25 mm	Spring loaded release button	60kg	12V



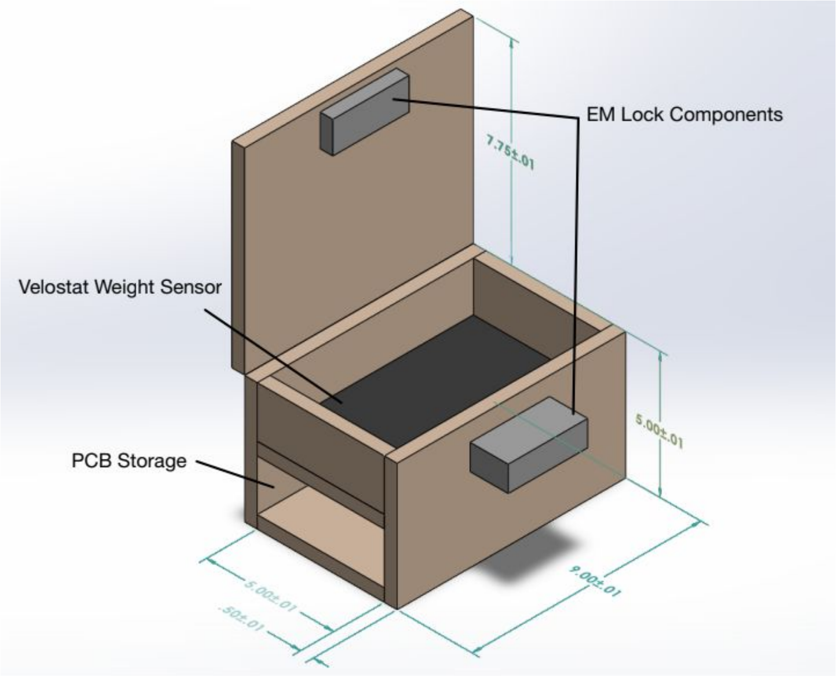
LED Notification Circuit

- Used to help user identify when it is time for a study break, as well as when they need to return their phone back to the magnetic locking box.
- Consists of input from microcontroller pin, series resistor and LEDs in parallel.



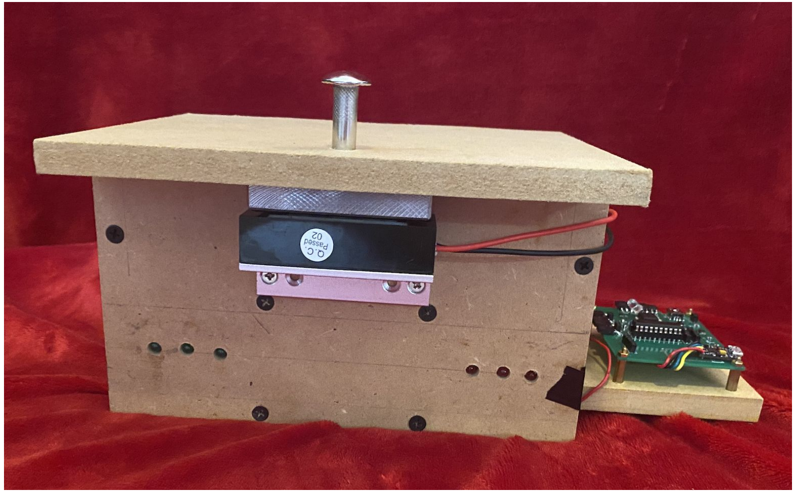


Phone Lockbox Model

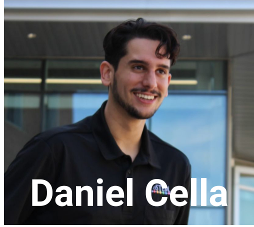


- Wood Housing
  - Cheap, easy to work with
- Compartment For PCB
  - Easily accessible while giving PCB a dedicated storage space

Phone Lockbox Prototype

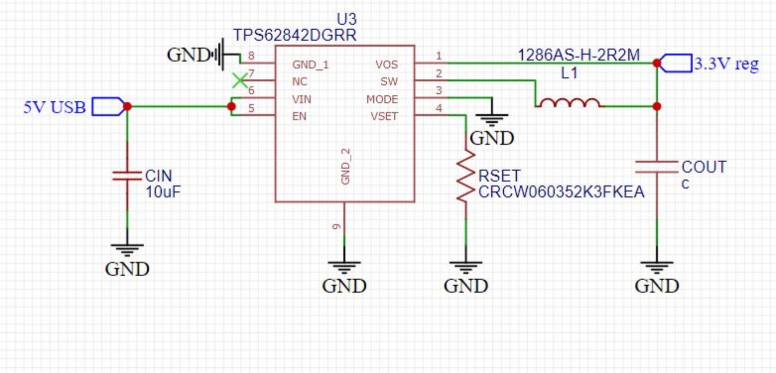


Main Desk Power Design



1) USB Power

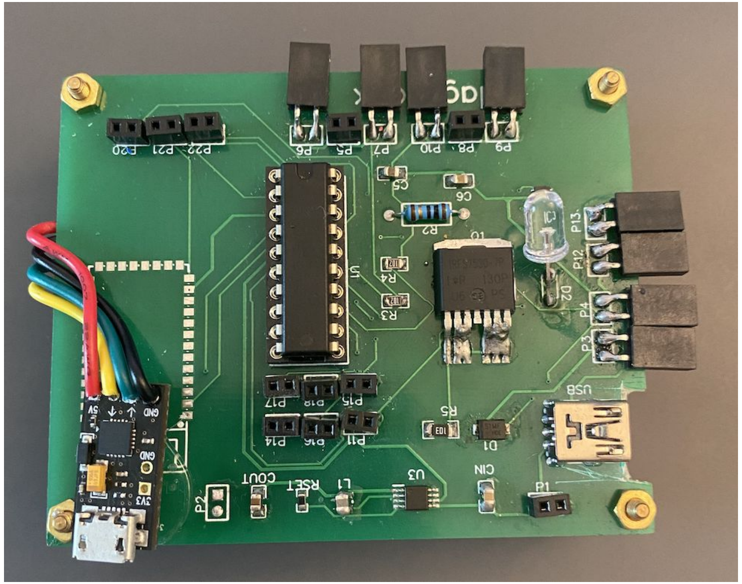
- USB able to supply 5V at
- 5V used to power the Velostat weight sensing circuit and intended bluetooth module
- 5V to 3.3V Power converter implemented using WEBENCH Designer tool

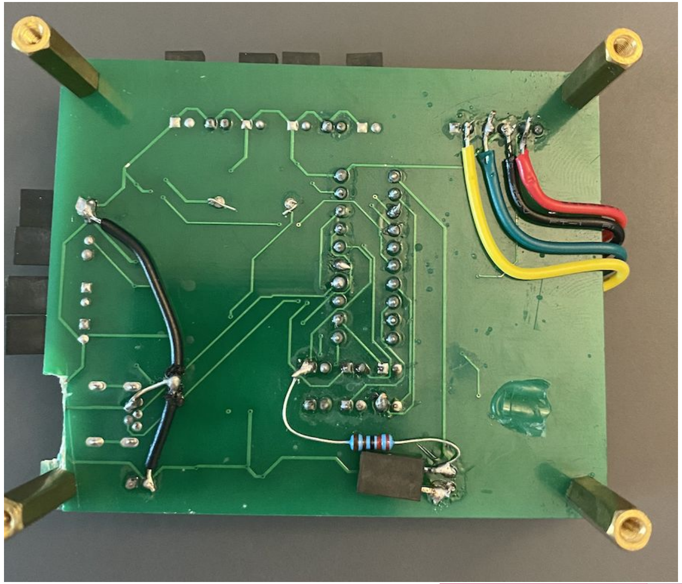


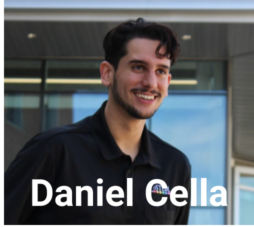
2) Mag Lock

- Maglock requires 12V to operate
- 12V battery to be implemented, hidden within the lockbox.
- Allows better portability of the apparatus and battery exchange once worn out

Lock Box PCB

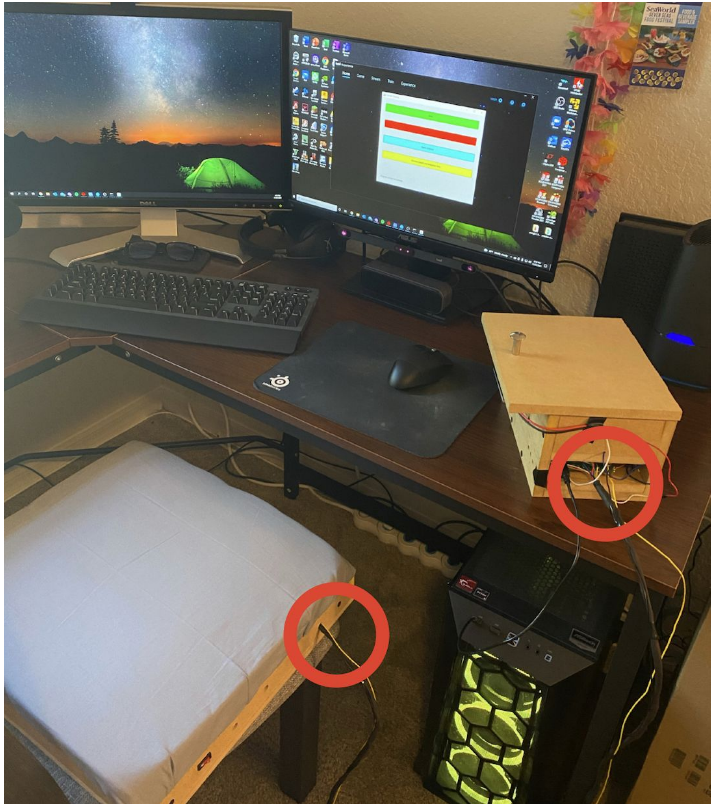






Chair Module

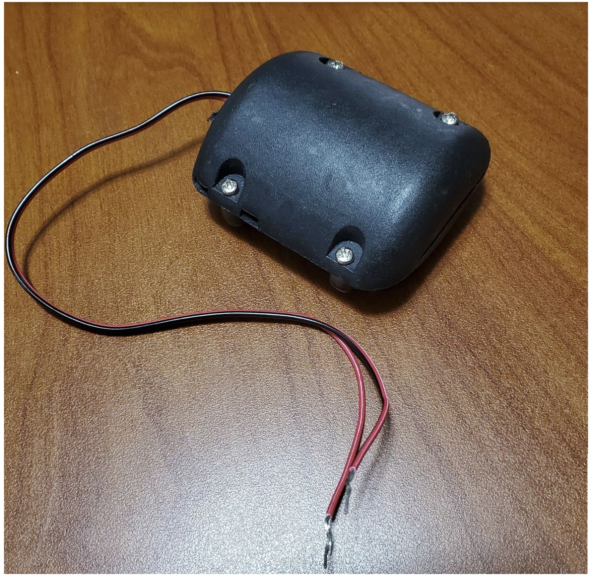
Chair Module Connections



- Only one MCU now on the lockbox
- Chair PCB still being used with everything routed to main module

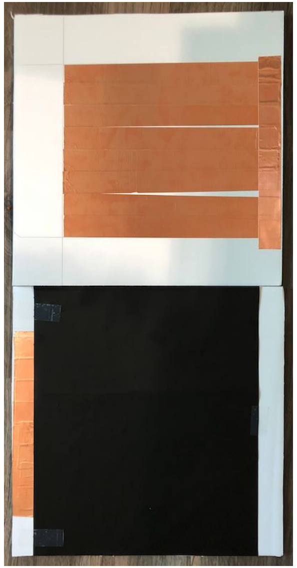
Vibration Motors

- 12V Encased Motor
  - Eccentric Rotating Mass (ERM) motor
    - 5000 rpm
  - Designed for use in massage chairs
- Hard case for motor
  - Easily incorporated into seat



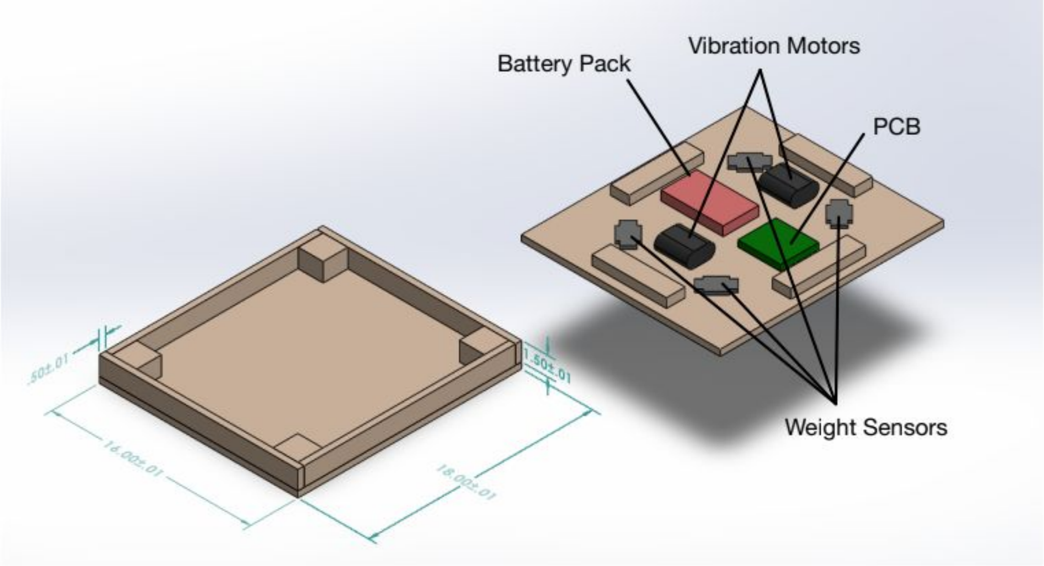
Item Name	Voltage Requirement	Size	RPM	Cost
Coin Vibration Motors	3 V	10 mm x 2.7 mm	12000	$8.99 (pack of 12)
Linear Resonant Actuator	3 V	10 mm x 3 mm	1200	$14.99 (pack of 20)
ERM Motor	12 V	2.6 in x 2.3 in	5000	$11.59 (pack of 2)

Chair Weight Sensor



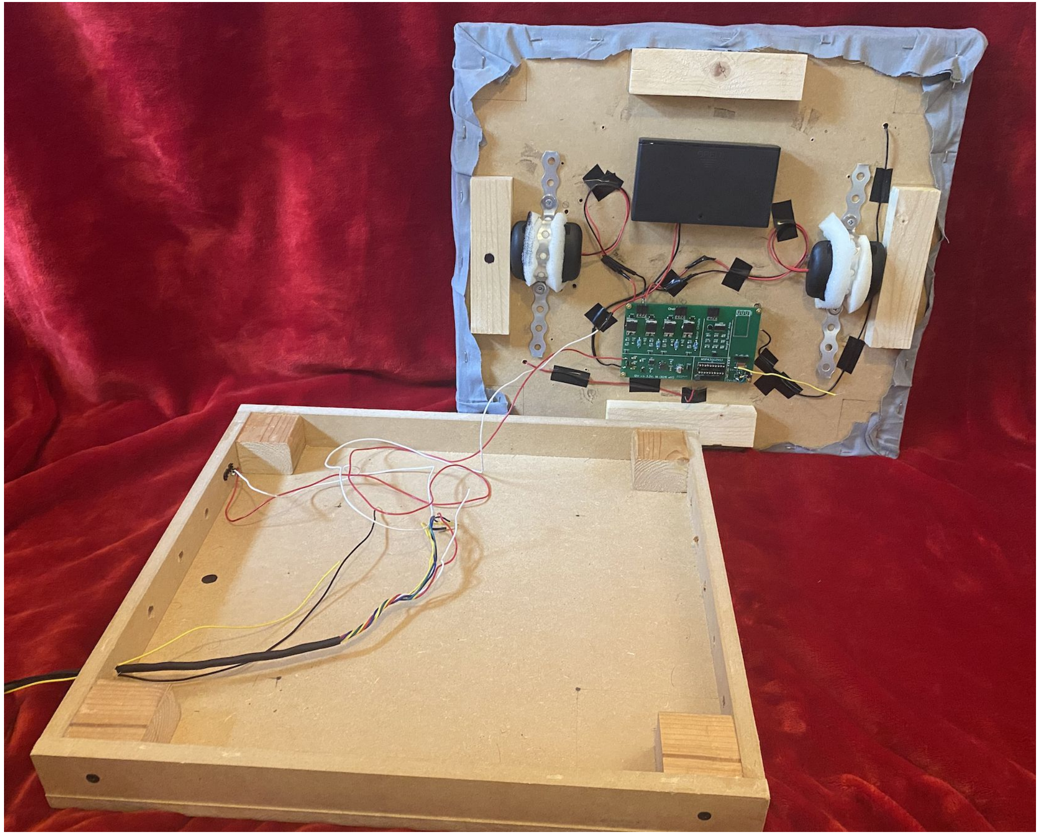
- Strain Gauge Load Cells
  - 50 kg (~110 lbs) each
  - Total of 200 kg (~441 lbs)
- Used in Household Scales
  - Designed for reading human weight
- HX711 Amplifier Circuit
  - Used to connect sensor readings to microcontroller
  - Incorporated into our pcb design
- Issues Reading Values
  - Time constraints forced a change to large velostat sensor

Chair Module Model

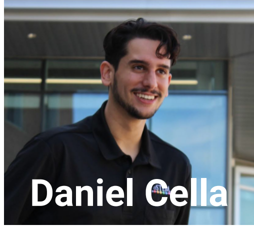


- Wood Housing
  - Cheap, easy to work with
- Components Mounted to Bottom Side of Seat Top
  - Space inside allows all components to be contained within the module

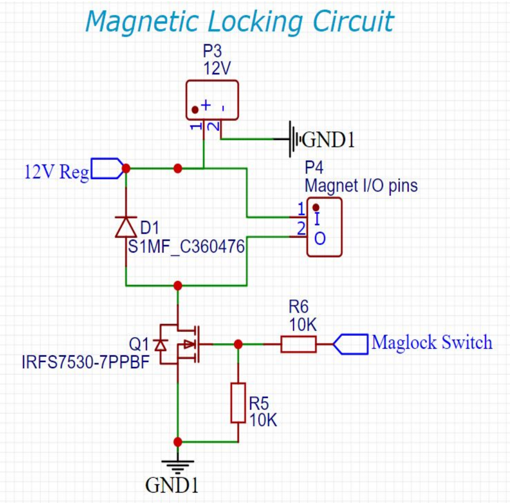
Chair Module Prototype



Switching Mechanism: MOSFET Selection

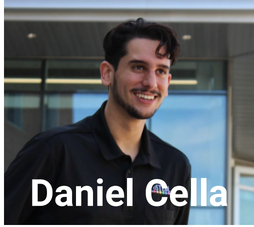


- Needed a switch for motors & magnetic lock
  - Each core circuit item powered by 12V source.
  - 3.3V Low-voltage microcontroller signal sent to open/close circuit for desired result, but not enough to activate the circuit.
  - Mosfet selected over relays for minimal mechanical parts: longevity, less fatigue
  - Desire to design fully integrated switching circuit



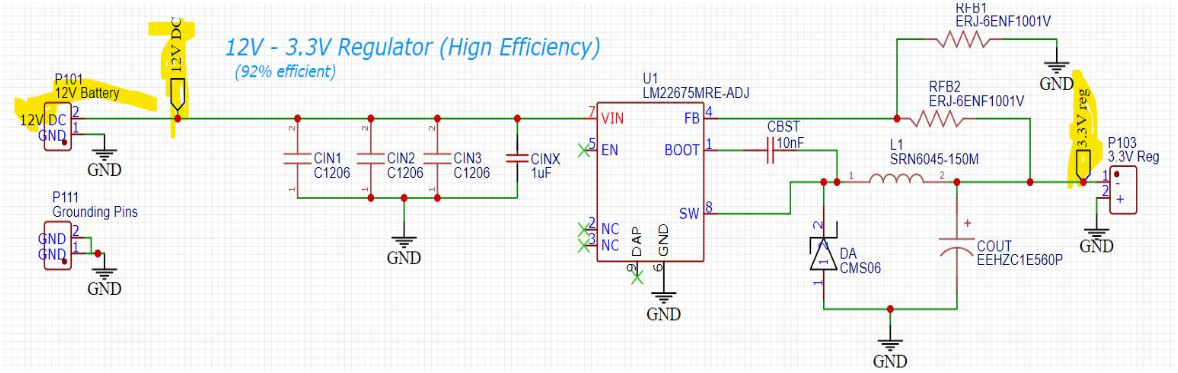
Item Name	Design Complexity	Mechanical Switching?	Integration?	Switching Voltage	Cost ($)
Designed MOSFET switch	Design required	No	Can be fully integrated into PCB	5V: driver needed	~7.50 (single channel)
Solid State Relay (SSR)	Prefabricated	No	Black box: external connections required	3.3V	7.99 (1 channel)
Physical Relay	prefabricated	Yes: flexing armature	Can be implemente d into PCB	3.3V available	11.99 (2 channel)

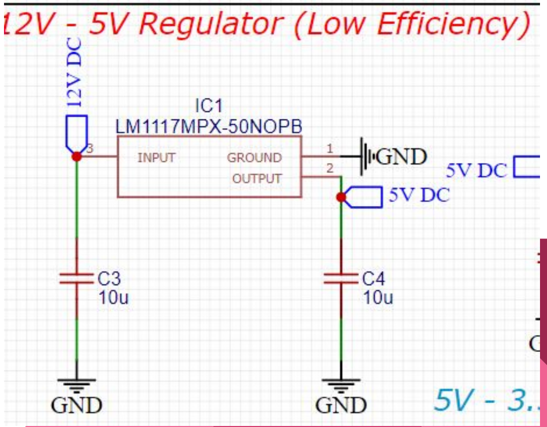
Chair Power Circuit



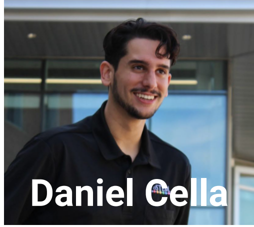
Microcontroller, weight Sensor, Bluetooth & Motor Power

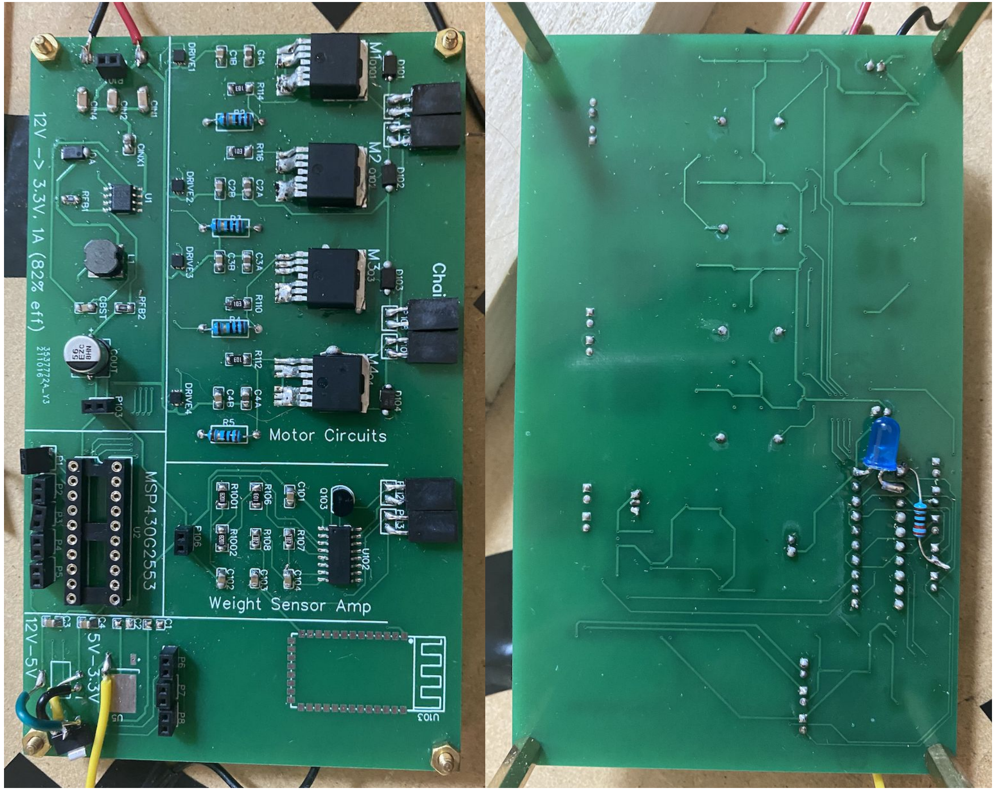
- 12V battery pack used to power all elements of this remote system.
- 12V - 3.3V DC-DC converter used to power the microcontroller.
- 12V-5V DC-DC converter used to power the bluetooth module and weight sensor.
- Motors powered straight from the battery pack.





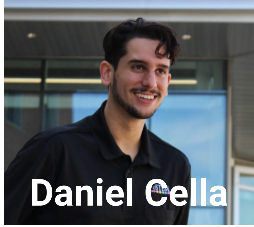
Chair Module PCB





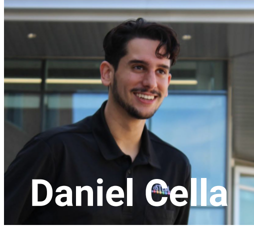
- More space allowed in chair module: much neater layout
- Sections allocated to respective design elements
- Critical changes (explained further in demo):
  - Microchip removed for hard wiring
  - Load cell system obsolete, velostat sensor used, current limiting diode implemented
  - 12V to 5V converter roached

Difficulties for Subsystems: PCB Design



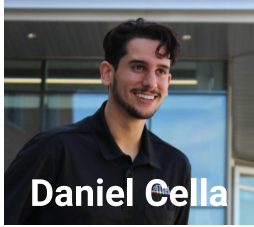
- Still unsure if initial 2 motors would be good enough to for the user to sense vibration
- Power circuits redesigned 3 different times due to parts going out of stock.
- Varied package microcontroller backups needed to be ordered as a result of only 2 SMT versions being available online.
- Difficulty finding parts large enough to be hand soldered in order to save money creating final board.
- Personal deadlines for PCB design submission not met due to redesigns needed for above problems.

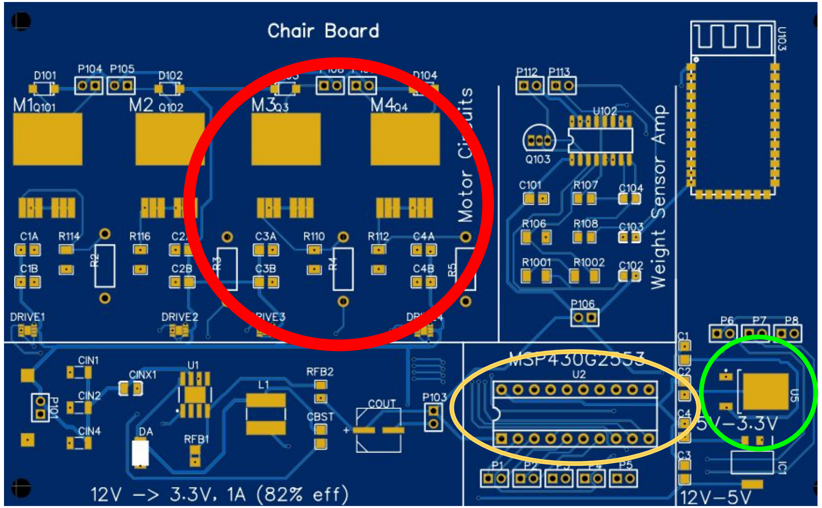
PCB Solution: Backups, Backups, Backups!

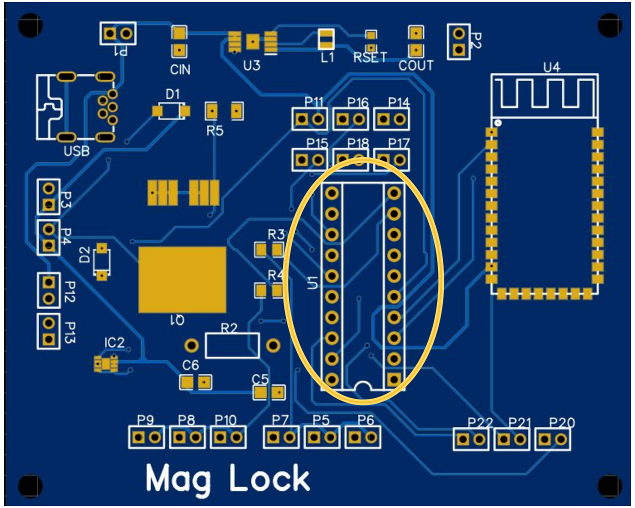


- 2 extra locations are designated for vibration motor circuits in case 2 vibration motors are not enough.
- An extra, less efficient 5V to 3.3V converter designed, unpopulated, for fear of our 12V-3.3V converter not working.
- Dip Chip option was preferred due to better part availability
- Better to do redesigns, include unpopulated PCB space, account for correctly sized components and increase chances of functionality than order boards that could fail or are unable to properly fabricate.

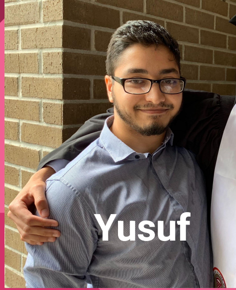
PCB Solution: Backups, Backups, Backups!







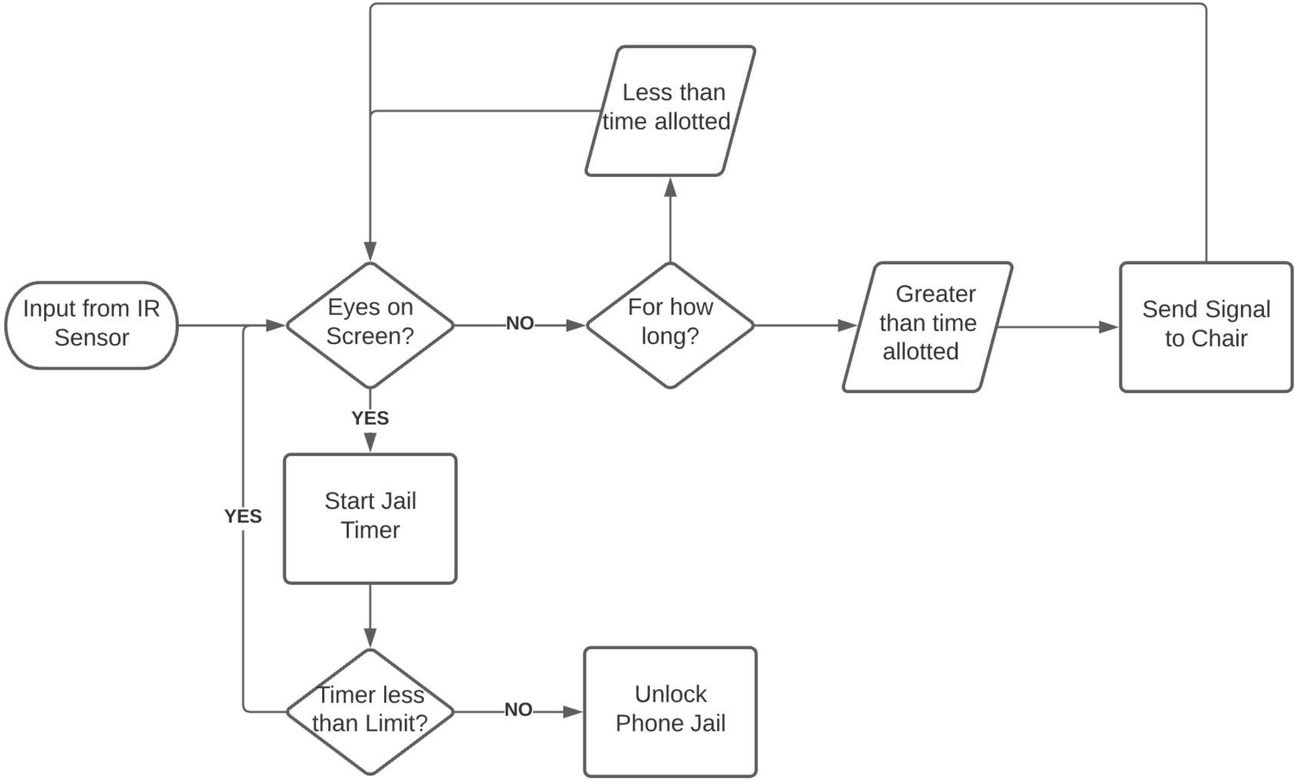
Software



Software Overview

- Eye tracking software
- User Interface
- microcontroller communication

Software Flowchart



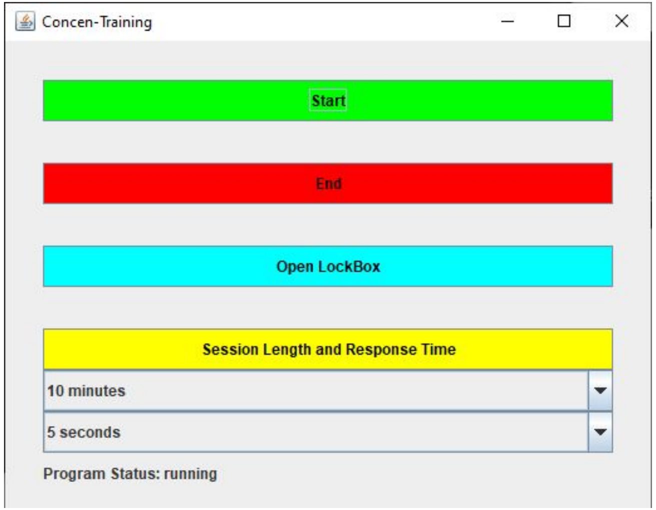
Eye-Tracking Software

- The eye tracking software is written in C code
- Tobii SDK for C programming
- C code is also a good bridge between the eye tracker and microcontrollers

PROGRAMMING

User Interface Software

- The user interface is written in Java
- The purpose of the user interface will be to allow users to start, end and configure the eye tracking software at will without having to look at or touch code



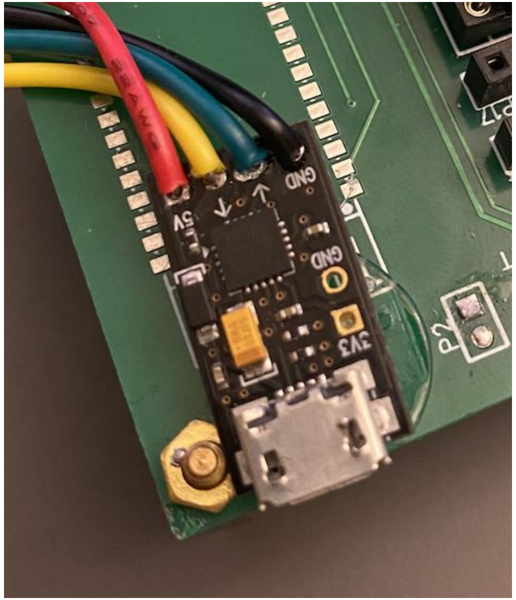
Wireless Communication Selection

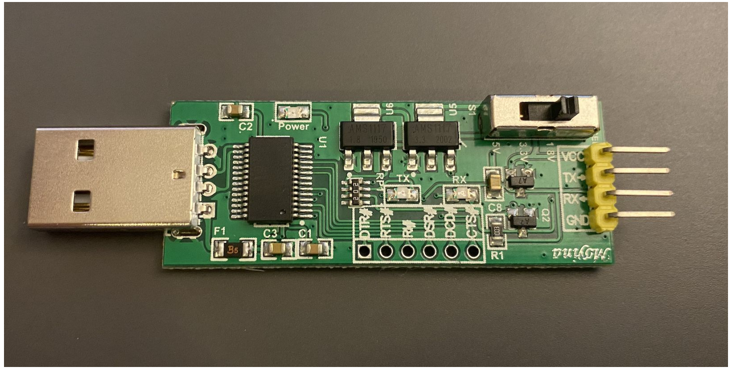
- WiFi was considered but we ultimately went with bluetooth because we will be sending small chunks of data and internet access is not necessary
- MCUs selected do not have wireless communication built in
- Supported baud rate: 9600, 19200, 38400, 57600, 115200, 230400, 460800

		Wireless Communication Modules			
		HC-05	Bluefruit LE SPI Friend	Bluefruit LE UART Friend	HM-10
Features	Price	\$7.99 (1) or \$12.59 (2)	\$17.50	\$17.50	\$9.99
	Operating Voltage	4V - 6V	3.6V - 6V	3.6V - 6V	2V - 3.6V
	Range	100 m	10 m	10 m	100 m
	Communication	USART	SPI	UART	UART

USB to UART Converter

- Needed to communicate between the PC and MCU
- Two options were purchased since this was a last minute change





Microcontroller Language

- Code Composer Studio is the IDE designed for Texas Instruments embedded processors (MSP430s)
- C/C++ can be used in CCS
- TI offers many helpful resources for programming MSP430s

motor.bat - Notepad

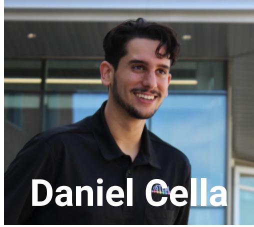
File Edit Format View Help

```
mode COM7 BAUD=9600 PARITY=n DATA=8
set /p x="t" <nul >\\.\COM7
```

```
#pragma vector = USCIAB0RX_VECTOR
__interrupt void EUSCI_A0_RX_ISR(void)  //arbitrary name
{
    if(UCA0RXBUF == 't')            // clears flag automatically
    {
        P2OUT ^= m1 + m2;           // turn on motors
    }
```

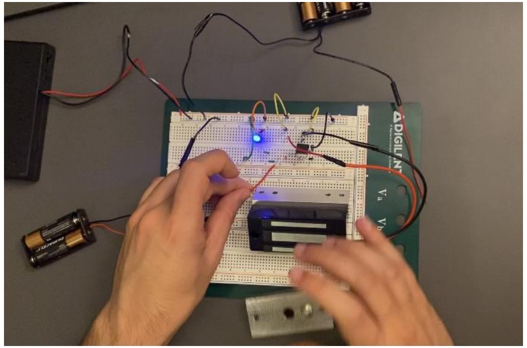
- USB from main module to computer - UART
- Batch file sends signal to CCS code to toggle motors

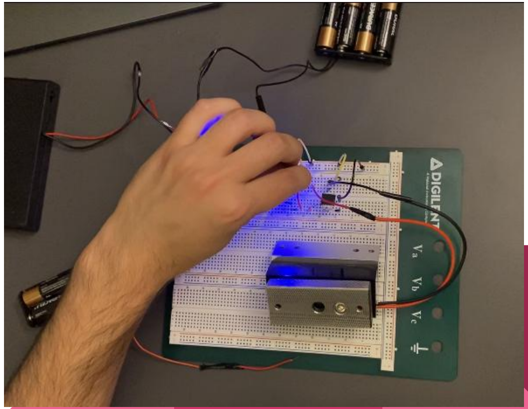
Testing/Critical Design Changes



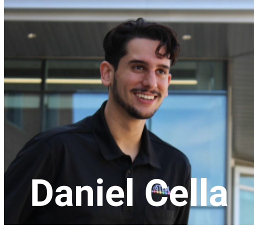
MOSFET Circuit Testing: Driver Implementation

- Since it is a critical circuit, we sacrificed one component to test a sample switching circuit
- Since it was a soldermount piece, wires were soldered to respective phalanges to connect via breadboard.
- Circuit did not switch with 3.3V from microcontroller, but did work when 6V battery was applied to gate. Thus, learned that a 5V+ driver was needed per each mosfet switching circuit.



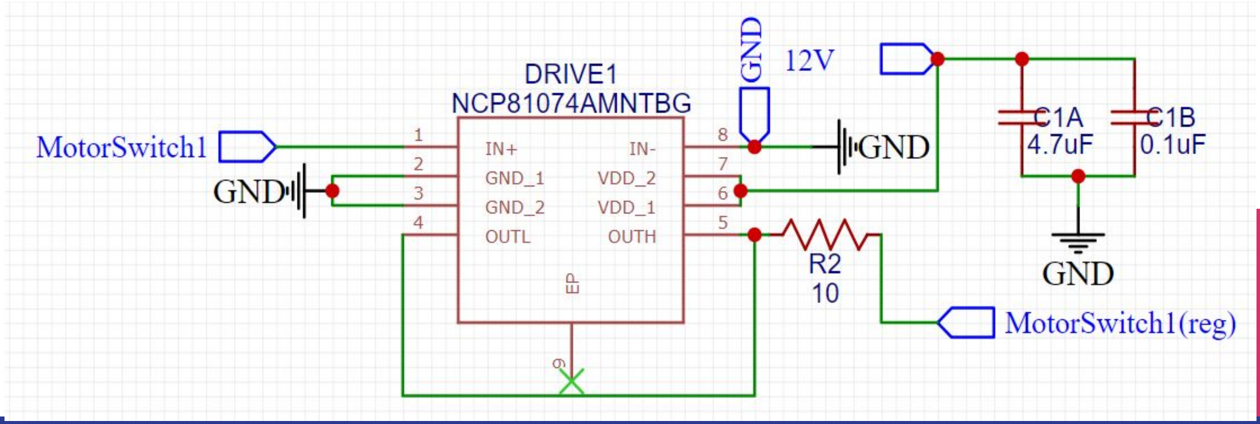


MOSFET Circuit Testing: Driver Implementation

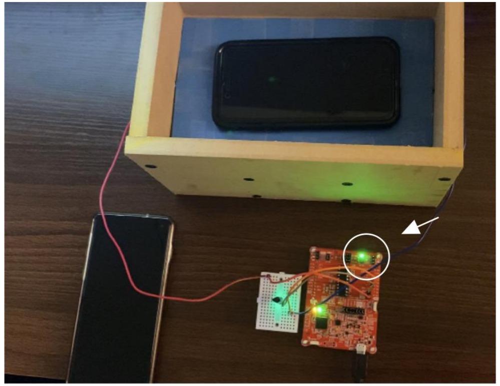


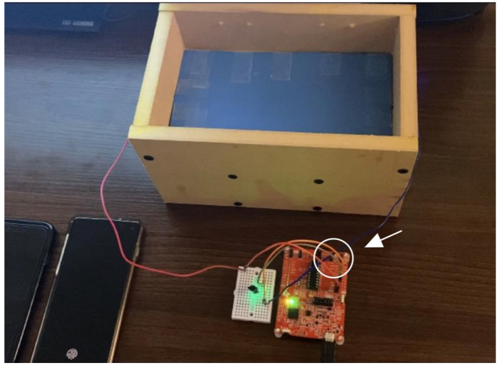
The driver circuit below was implemented into our final PCB design

- Inputs 12V and 3.3V microcontroller signal voltage
- Converts controller signal into 5V, which is able to activate MOSFET gate.
- Minimal components, not huge cost addition



Weight Sensor Testing

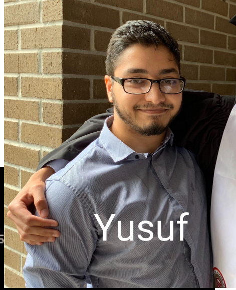




- Test Performed on LaunchPad
- Set Up ADC10 On MSP430
- Determined Threshold Value
  - Used analog reading inputs to find threshold for determining if phone is placed inside
- Toggle Green LED When Phone is Present
  - Used to simulate activation of LEDs in final design when phone is present in box

```
void init_adc()
{
    ADC10CTL0 = ADC10ON;      //turn on ADC10
    ADC10CTL1 |= INCH_3;       //Select channel 3 (A3 of P1.3),
    ADC10AE0 |= BIT3;         //Enable analog input on A3(P1.3)
    ADC10DTC0 = 0x04;         //Continuously transfer data
}
```

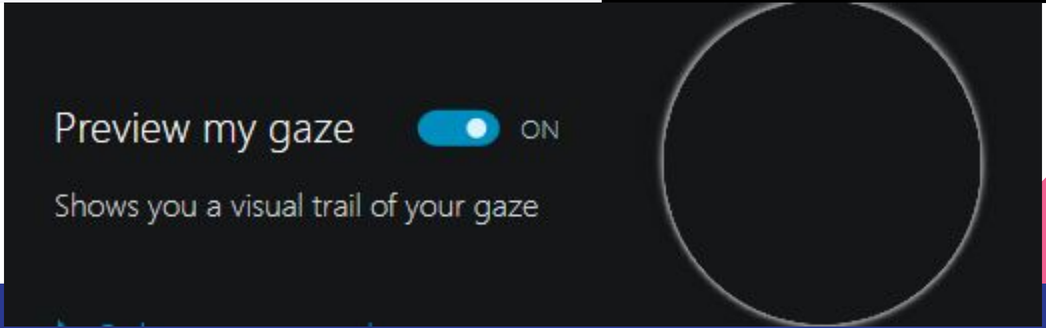
Eye-tracking Testing



Such a screen region is called an *interactor* in the Interaction Library API.

```
A screen with 4 "corner" interactors A, B, C and D:

                 2560
  +-------+-------------------+-------+
  |   A   | 500           500 |   B   |
  +-------+                   +-------+
  |  500                         500  |
  |                                   |  1440
  |  500                         500  |
  +-------+                   +-------+
  |   C   | 500           500 |   D   |
  +-------+------------------ +-------+
```

```
left side Interactor: 5, focused: true, timestamp: 153546841361 us
left side Interactor: 5, focused: false, timestamp: 153546901486 us
bottom left corner Interactor: 2, focused: true, timestamp: 153546901486 us
bottom left corner Interactor: 2, focused: false, timestamp: 153547354509 us
left side Interactor: 5, focused: true, timestamp: 153547354509 us
left side Interactor: 5, focused: false, timestamp: 153547384861 us
top left corner Interactor: 0, focused: true, timestamp: 153547384861 us
top left corner Interactor: 0, focused: false, timestamp: 153547686288 us
top middle Interactor: 4, focused: true, timestamp: 153547686288 us
top middle Interactor: 4, focused: false, timestamp: 153547747063 us
top right corner Interactor: 1, focused: true, timestamp: 153547747063 us
top right corner Interactor: 1, focused: false, timestamp: 153548018657 us
right side Interactor: 6, focused: true, timestamp: 153548018657 us
right side Interactor: 6, focused: false, timestamp: 153548049190 us
top right corner Interactor: 3, focused: true, timestamp: 153548049190 us
top right corner Interactor: 3, focused: false, timestamp: 153548469966 us
bottom middle Interactor: 7, focused: true, timestamp: 153548469966 us
bottom middle Interactor: 7, focused: false, timestamp: 153548498252 us
middle area Interactor: 8, focused: true, timestamp: 153548498252 us
middle area Interactor: 8, focused: false, timestamp: 153548531610 us
top middle Interactor: 4, focused: true, timestamp: 153548531610 us
top middle Interactor: 4, focused: false, timestamp: 153548622177 us
top left corner Interactor: 0, focused: true, timestamp: 153548622177 us
top left corner Interactor: 0, focused: false, timestamp: 153548804358 us
left side Interactor: 5, focused: true, timestamp: 153548804358 us
left side Interactor: 5, focused: false, timestamp: 153550072594 us
bottom left corner Interactor: 2, focused: true, timestamp: 153550072594 us
bottom left corner Interactor: 2, focused: false, timestamp: 153550102156 us
left side Interactor: 5, focused: true, timestamp: 153550857337 us
```

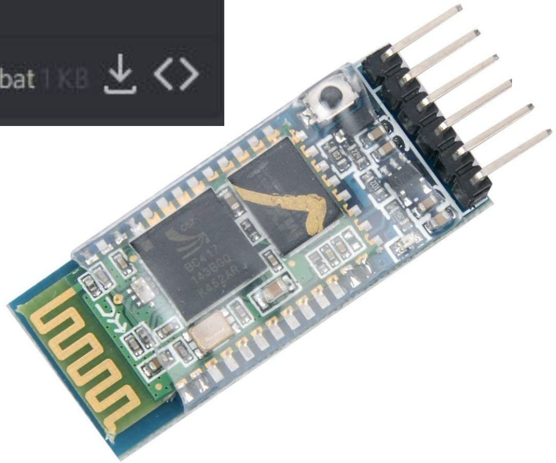


Bluetooth Testing (PC to MCU)

```
mode COM7 BAUD=9600 PARITY=n DATA=8
set /p x="t" <nul >\\.\COM7
exit
```

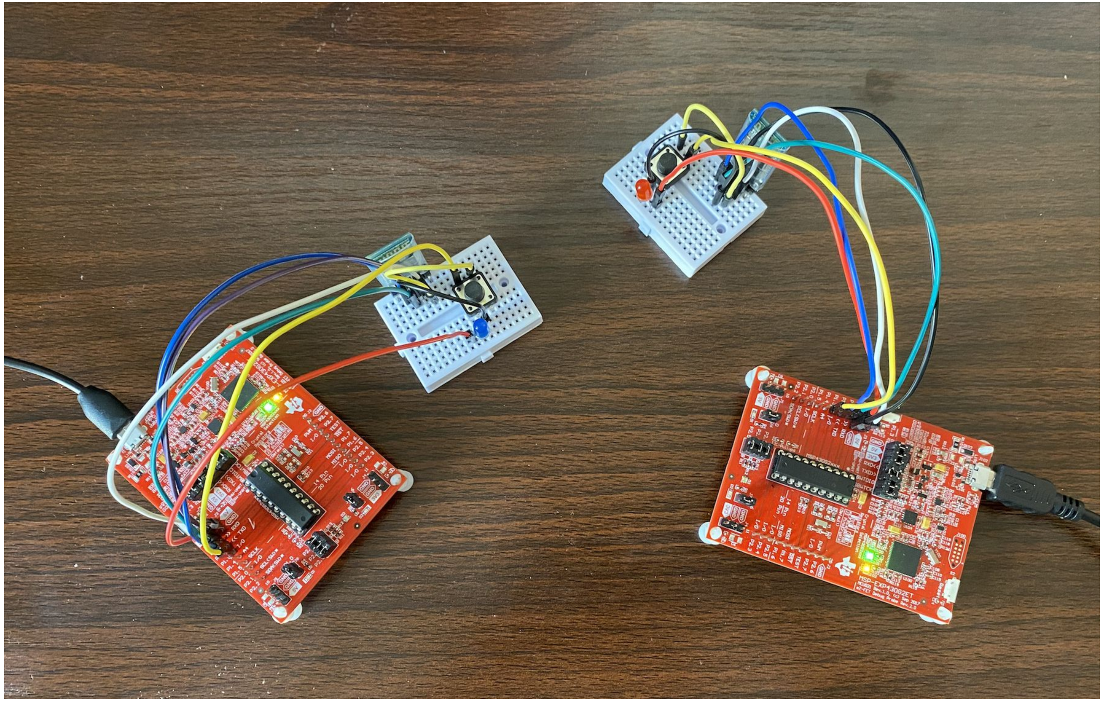
motor.bat 1 KB

BlueZ



Linux™

Bluetooth Testing (MCU to MCU)



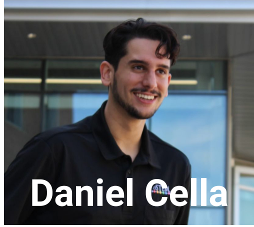
```
    while(1){

        // Controlling the LED on A
        state = uart_read_char();   // received button state on B

        if(state == '1') // if button pressed on B
        {
            P1OUT ^= BIT0; // turn LED on
        }
        else
        {
            P1OUT &= ~BIT0; // button not pressed, turn off
        }


    }  // do nothing

}

void uart_write_char(unsigned char ch)
{
    // Wait for any ongoing transmission to complete
    while ( (FLAGS & TXFLAG) == 0 ) {}

    if((P1IN & button) == 0) // if button pressed
    {
        ch = '1';
    }
    else
    {
        ch = '0';
    }

    // Write the byte to the transmit buffer
    TXBUFFER = ch;
}

// The function returns the byte; if none received, returns NULL
unsigned char uart_read_char(void)
{
    unsigned char temp;

    // Return NULL if no byte received
    if( (FLAGS & RXFLAG) == 0)
    {
        return 0;
    }

    // Otherwise, copy the received byte (clears the flag) and return it
    temp = RXBUFFER;
    return temp;
}
```

Specification Testing

Spec Number	Item	Specification	Acceptable Range	Averaged Test Data
1	Eye-Tracking Accuracy	>90% accuracy	+/- 5%	95%
2	Eye-Tracking Registration Distance	1 meter	+/- 20 cm	1 meter
3	Eye-Tracking Response Time	Within 2 seconds	+/- 0.5 seconds	milliseconds
4	Set-up Time	<10 minutes	+/- 2 minutes	5 minutes
5	Chair Module Size	<1 Square Foot	+/- 3 inches (length)	18 x 16 inches
6	Inactivity Threshold	~10 seconds	+/- 5 seconds	5 seconds
7	Alerting Threshold	~3 seconds	+/- 1 second	<1 second
8	Vibration Module Power	3.3-5 Volts	N/A	12 Volts
9	Communication Module Power	3.3-5 Volts	N/A	3.3 Volts
10	Smart Lock Box Size	9" x 9" x 9"	+/- 2 inches in each dimension	9.25" x 7.75" x 5.375"
11	Cable Length (Computer to Box)	~1 meter	+/- 30 cm	~53 cm

Administrative

Budget Breakdown for Concen-Training System

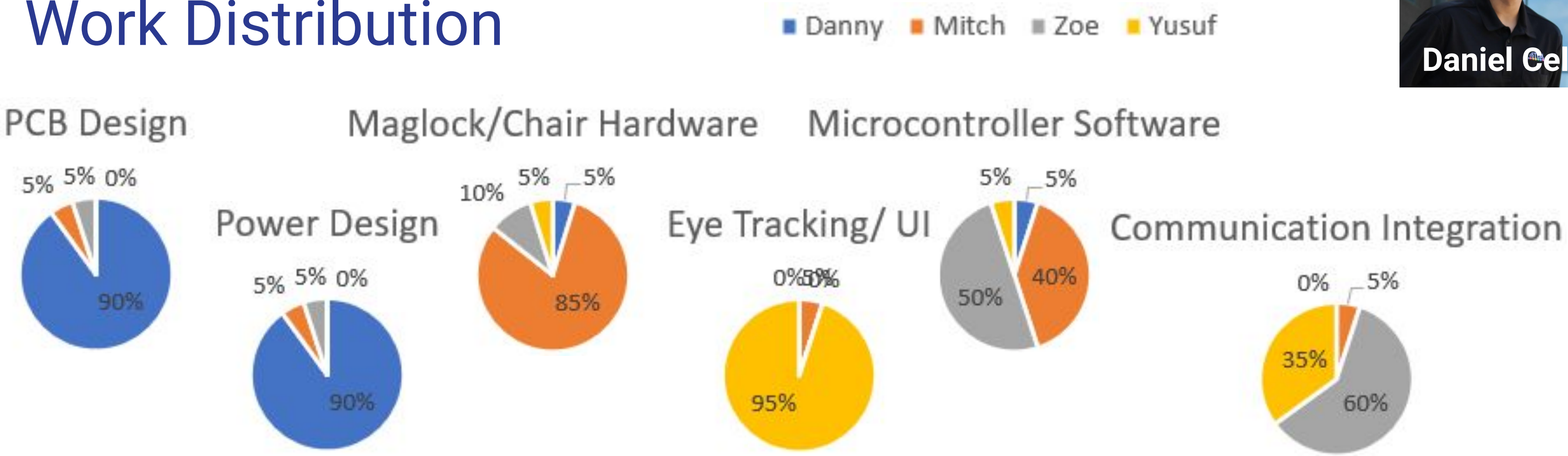


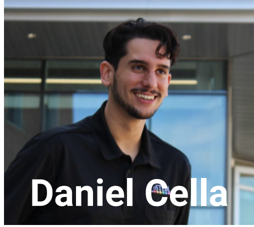
Subject	Index	Item	Price ($)	Subsection Total
Key Hardware	1	EM Lock	16.89	-
Key Hardware	2	Eye Tracking Cam	229	-
Key Hardware	3	Velostat (2 sheets)	9.9	-
Key Hardware	4	Copper Tape	10.99	-
Key Hardware	5	HC05 bluetooth mod	12.59	-
Key Hardware	6	Vibration Motors (4)	23.18	-
Key Hardware	7	USB-UART Converter	10.6	-
Key Hardware	8	Load Cell Hardware	8.49	**321.64**
Power	9	2 12V AA battery packs	7.99	-
Power	10	DC Plugs (testing)	11.99	**19.98**
PCB	11	mouser components	178.72	-
PCB	12	digikey components	40.77	-
PCB	13	JCL PCB	66.33	-
PCB	14	small component soldering	0 (courtesy of QMS)	**285.82**
Misc. Hardware	15	wiring	14.99	-
Misc. Hardware	16	LED lights	6.55	-
Misc. Hardware	17	housing hardware	22.99	-
Misc. Hardware	18	Physical Switches and Tubing	8.52	-
Misc. Hardware	19	housing material (wood)	36.98	-
Misc. Hardware	20	load cell housing (printed)	5	-
Misc. Hardware	21	cusion and fabric	5	**100.03**
TOTAL COST:	-	-	-	**722.47**

$122.47 over predicted budget of $600

- Around $181 per student
- Satisfied with final expenditures outcome
- Much of unexpected costs from component shipping: multiple orders needed for redesigns, component shipping is expensive

Work Distribution





- **Danny**:
  - Primary: PCB Design (90%), Power Design (90%)
  - Secondary: Microcontroller Software (5%)
- **Mitch**:
  - Primary: Chair and Lockbox Hardware (85%), Microcontroller Software (40%)
  - Secondary: PCB Design (5%), Power Design (5%), Communication Integration (5%)
- **Yusuf**:
  - Primary: Eye Tracking & User Interface (100%), Communication Integration (35%)
  - Secondary: Microcontroller Software (5%), Hardware (5%)
- **Zoe**:
  - Primary: Microcontroller Software (50%), Communication Integration (60%)
  - Secondary: Chair and Lockbox Hardware (10%), PCB Design (5%), Power Design (5%)

Stretch Goals

- Make original design function as planned
- Desktop icon for UI
- More customization: longer study sessions, stretch breaks, etc
- Determine what is on the user’s screen: study material vs video games
- Data tracking to view study streaks

Concen-Training System

Concen-Training System